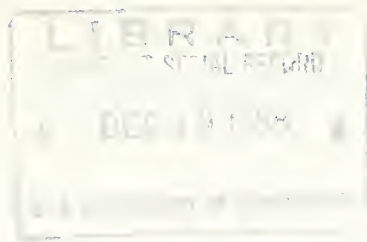


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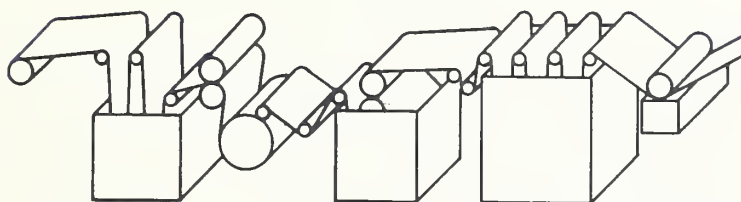
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# PARTIAL ACETYLATION OF COTTON

Preliminary Cost Studies



Agricultural Research Service  
UNITED STATES DEPARTMENT OF AGRICULTURE

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## ABSTRACT

In recent years considerable progress has been made in the chemical modification of cotton. Processes for the partial acetylation of cotton yarn and fabric were developed at the Southern Utilization Research and Development Division, Agricultural Research Service, as part of a research program to expand cotton utilization in products having specific properties. Partially acetylated (PA) cotton has outstanding resistance to deterioration by microorganisms and heat, and has been found to have unusually long service life in various applications such as sandbags, commercial laundry press cloths, household ironing board covers, and water softener bags.

This paper gives investment costs, operating expenses, and estimated service charges and break-even points at two profit levels for hypothetical partial acetylation installations. The estimated manufacturing cost for partially acetylating cotton yarn to 15 percent acetyl content in a continuous process, involving processing about 54 million pounds of scoured yarn annually with reasonable chemical recovery, is 14.2 cents per pound of product.

# PARTIAL ACETYLATION OF COTTON--PRELIMINARY COST STUDIES

by

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## INTRODUCTION

Processes for the partial acetylation of cotton yarn and fabric were developed at the Southern Utilization Research and Development Division, A.R.S., as a part of a research program to expand cotton utilization in products having specific properties. This chemically modified cotton product has outstanding resistance to deterioration by microorganisms and heat, and has been found to have unusually long service life in various applications such as sandbags, commercial laundry press cloths, household ironing board covers, and water softener bags (2, 3, 4, 6, 7).<sup>3</sup>

It is difficult to estimate the market potential for PA cotton material because its possible uses are many and varied. In addition to those mentioned above, its uses for convertible tops, awnings and tarpaulins, fishing supplies, conveyor belts, filter bags, hot mill gloves, shoe fabrics, and industrial thread might be included. For each end-use PA cotton and the competing materials, such as man-made fibers, wood, various metals, and cotton, must be considered relative to their service life, price, quality, appearance, heat- and hot-resistance, strength, weight, absorbency, and construction, before an accurate market potential of PA cotton can be determined. However, it is estimated that about 800,000 bales of cotton and 110 million pounds of man-made fibers, mostly noncellulosic, (equivalent to about 220 million pounds of cotton), go into industrial end-uses in which one or more of the improved properties of PA cotton might be advantageous. It cannot be expected that all of these materials will be replaced by PA cotton; nevertheless, considerable market potential is indicated.

For consideration of what the future might hold for PA cotton by way of expanded utilization, three preliminary cost estimates for the production of chemically modified yarn and fabric are presented. The cost estimates are for processing "by contract" and exclude the cost of untreated cotton yarn or fabric. Each cost estimate includes calculated unit service charges for processing including profits, at levels representing investment payout periods of 2 and 5 years.

One cost estimate is based on the construction and operation of a hypothetical large-scale continuous plant with a capacity for partially acetylating cotton yarn at a rate in excess of 50 million pounds annually. The additional cost estimates are predicated on hypothetical expansion of an existing textile finishing plant to include the production of PA cotton yarn and fabric at selected production capacities as low as approximately two and one-half million yards of 2-yard sheeting or equivalent annually.

## THE PROCESS

The essential steps of the SURDD process for continuous partial acetylation of cotton, schematically diagrammed in Figure 1, are three: Pretreating or activating the cotton yarn or fabric with acetic acid-acetic anhydride solution, impregnating it with perchloric acid catalyst, and reacting it with acetic anhydride. These are followed by catalyst inactivation with potassium acetate and subsequent washing and drying. A chemical balance and complete flow diagram for the continuous partial acetylation process is shown in Figure II.

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<sup>3</sup> Numbers in parentheses refer to Literature Cited at the end of this publication.

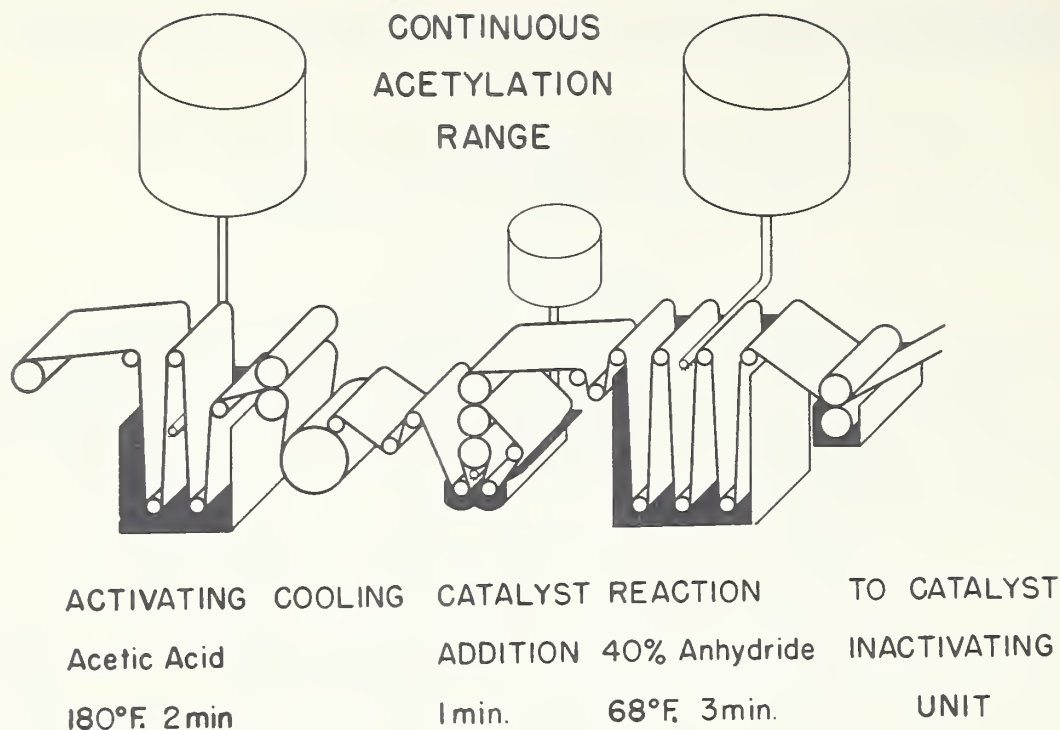


Figure 1.--Continuous acetylation range.

Processing begins with desized or scoured cotton material entering into a continuous range at a normal moisture content, assumed to be about 7-1/2 percent for these estimates.

The first step--activation of the cotton--is carried out at 180° F. in a bath of glacial acetic acid and sufficient acetic anhydride to combine with the normal moisture content. The cotton remains in the bath approximately 2 minutes, is squeezed to the required carry out, and then cooled by either acid evaporation of the carry out and/or passage over a cooling roll or "can."

The second step--the catalyst addition bath--is to pass the activated cotton material into this bath containing approximately 5 to 6 percent of perchloric acid catalyst dissolved in glacial acetic acid. The primary function of this step is uniform impregnation of the cotton fiber structure with catalyst. Squeeze roll pressure is regulated to obtain optimum carry out of the catalyst solution.

The third step--or reaction--is carried out in a solution approximately 40 percent acetic anhydride and 60 percent acetic acid. Reaction proceeds to the desired degree of completion at about 68° F. in approximately 3 minutes. After the reaction step, the cotton material is squeezed to remove as much of the chemicals from the cotton as possible. Care must be exercised in squeezing, because the cotton material at this stage of processing is in its weakest state and may be damaged by excessive pressure. Solution removed by the squeeze rolls contains acetic anhydride and acetic acid, in sufficient quantity and of proper concentration to feed the activation bath, and also a small quantity of catalyst. Before this solution can be fed to the activation bath, the catalyst must be inactivated to prevent degradation of the cotton at the elevated temperature of the activation bath.

PA cotton containing acetic anhydride, acetic acid, and perchloric acid is then passed through a bath of potassium acetate and water to inactivate the perchloric acid and to hydrolyze the acetic anhydride.



Then the partially acetylated product is thoroughly washed to remove the remaining chemicals, and dried. Thorough washing is essential to prevent degradation which would result from excess acid retention.

## INVESTMENT COSTS

### Plant Investment

Estimated total plant investment costs for the various capacity continuous partial acetylation plants for processing yarn and fabric are shown in Table I. The percentages used in estimating the total plant costs were selected from published information (1, 5, 8).

Table I. ESTIMATED PLANT INVESTMENT COST

#### YARN PROCESSING

| Item                                              | Large separate plant <sup>1</sup> | Plant as an addition to an existing textile mill <sup>2</sup> |         |         |
|---------------------------------------------------|-----------------------------------|---------------------------------------------------------------|---------|---------|
|                                                   |                                   |                                                               |         |         |
| (A) Plant capacity (M units).....pounds....       | 54,432                            | 3,780                                                         | 6,480   | 9,072   |
| (B) Annual operation.....days.....                | 350                               | 250                                                           | 250     | 350     |
| (C) Daily operation.....hours.....                | 24                                | 16 <sup>3</sup>                                               | 24      | 24      |
| (a) Installed equipment cost.....dollars...       | 1,116,772                         | 258,442                                                       | 275,703 | 289,825 |
| (b) Process piping, 13% of (a).....do.....        | 145,180                           | 33,597                                                        | 35,841  | 37,677  |
| (c) Instrumentation, 2% of (a).....do.....        | 22,335                            | 5,169                                                         | 5,514   | 5,797   |
| (d) Outside lines, 3% of (a).....do.....          | 33,503                            | 7,753                                                         | 8,271   | 8,695   |
| (e) Auxiliary facilities.....do.....              | 233,225                           | 35,664                                                        | 35,664  | 35,664  |
| (f) Buildings.....do.....                         | 660,300                           | 101,336                                                       | 101,336 | 101,336 |
| (g) Land & improvements.....do.....               | 26,100                            | -                                                             | -       | -       |
| (h) Total physical plant cost.....do.....         | 2,237,415                         | 441,961                                                       | 462,329 | 478,994 |
| (i) Engin. & construction, 20% of (h).....do..... | 447,483                           | 88,392                                                        | 92,466  | 95,799  |
| (j) Contingencies, 15% of (h).....do.....         | 335,612                           | 66,294                                                        | 69,349  | 71,849  |
| (k) Total plant cost.....do.....                  | 3,020,510                         | 596,647                                                       | 624,144 | 646,642 |

#### FABRIC PROCESSING

| Item                                              | Plant as an addition to an existing textile mill <sup>2</sup> |         |         |                    |                    |                     |
|---------------------------------------------------|---------------------------------------------------------------|---------|---------|--------------------|--------------------|---------------------|
|                                                   |                                                               |         |         |                    |                    |                     |
| (A) Plant capacity (M units).....yds.....         | 2,520                                                         | 4,320   | 6,048   | 5,040 <sup>4</sup> | 8,640 <sup>4</sup> | 12,096 <sup>4</sup> |
| (B) Annual operation.....days.....                | 250                                                           | 250     | 350     | 250                | 250                | 350                 |
| (C) Daily operation.....hours.....                | 16 <sup>3</sup>                                               | 24      | 24      | 16 <sup>3</sup>    | 24                 | 24                  |
| (a) Installed equipment cost.....dollars...       | 268,387                                                       | 268,387 | 286,427 | 310,520            | 310,520            | 336,971             |
| (b) Process piping, 13% of (a).....do.....        | 34,890                                                        | 34,890  | 37,236  | 40,368             | 40,368             | 43,806              |
| (c) Instrumentation, 2% of (a).....do.....        | 5,368                                                         | 5,368   | 5,729   | 6,210              | 6,210              | 6,739               |
| (d) Outside lines, 3% of (a).....do.....          | 8,052                                                         | 8,052   | 8,593   | 9,316              | 9,316              | 10,109              |
| (e) Auxiliary facilities.....do.....              | 12,374                                                        | 12,374  | 12,374  | 24,164             | 24,164             | 24,164              |
| (f) Buildings.....do.....                         | 114,238                                                       | 114,238 | 114,238 | 138,425            | 138,425            | 138,425             |
| (g) Land & improvements.....do.....               | -                                                             | -       | -       | -                  | -                  | -                   |
| (h) Total physical plant cost.....do.....         | 443,309                                                       | 443,309 | 464,597 | 529,003            | 529,003            | 560,214             |
| (i) Engin. & construction, 20% of (h).....do..... | 88,662                                                        | 88,662  | 92,919  | 105,801            | 105,801            | 112,043             |
| (j) Contingencies, 15% of (h).....do.....         | 66,496                                                        | 66,496  | 69,690  | 79,350             | 79,350             | 84,032              |
| (k) Total plant cost.....do.....                  | 598,467                                                       | 598,467 | 627,206 | 714,154            | 714,154            | 756,289             |

<sup>1</sup> A self-sustaining plant equipped with 4 continuous partial acetylation ranges and other necessary equipment for processing in excess of 50 million pounds of yarn annually.

<sup>2</sup> Plant is addition to an existing textile finishing mill and includes 1 continuous partial acetylation range and other necessary equipment for processing between about 3.8 and 9.1 million pounds of yarn and between 2.5 million and 12.1 million yards of 60-inch-wide, 2-yard sheeting or equivalent, annually.

<sup>3</sup> Net production time is 14 hours per day allowing 2 hours to start up and shut down.

<sup>4</sup> 2 thicknesses of material processed simultaneously.

The schematic plant layout in Figure III is for the smaller yarn plant. This layout is also applicable to the fabric plant except a tenter frame is used instead of dryer cans for drying the fabric. For the larger yarn plant the layout was planned at two elevations to accommodate larger equipment units, and three additional continuous ranges of the size shown in Figure III. Auxiliary systems were selected to meet the requirements of the four ranges. An evaporator is included in the auxiliary systems to remove from the chemicals certain impurities such as dirt and wax which accumulate after repeated reuse. Also in the acetylation of dyed materials, such as awnings, some dye is dissolved in the chemicals and must be removed prior to the reuse of such chemicals with nondyed or other dyed materials.

Installed equipment includes drives and their electrical controls and service, foundations, and supports. Piping within the process building exclusive of that for building service facilities is classified as process piping. Outside lines are process and utility piping and electrical lines external to the process building. Auxiliary facilities for processing are steam boilers, refrigeration equipment, a cooling tower, and an electrical substation; for the large plant, a service building is considered necessary.

Buildings are of steel, concrete, and brick, with service facilities included, such as heating, ventilation, sanitary plumbing, lighting, and sprinklers. In all cases, buildings are provided for processing and storage; also in the case of the large plant administrative offices and laboratories, with land and yard improvements.

Because the process is considered to involve only straightforward engineering practices, engineering and construction costs were estimated to be 20 percent of the physical plant cost. For this relatively firm process, contingencies costs to compensate for unforeseen expenses and estimating errors were assumed to be 15 percent of the physical plant cost.

### Working Capital

Working capital was determined for the normal conduct of business for processing yarn or fabric by contract, considering chemical stocks, product inventory, extended credit, in-process inventory, and available funds needed for wages and other expenses during a 4-week period.

Product inventory, extended credit, and available funds were estimated to be equal to 4 weeks' production of partially acetylated yarn or fabric valued at four times the processing cost. Working capital for chemical stocks was assumed equal to the purchase value of a 4-week chemical supply; and process inventory was considered equal to one-half the processing cost during an in-process hold-up time of 1 operating day.

The following equation, a modification of that expressed by Aries and Newton (1), was used in calculating working capital requirements for the various plant capacities:

$$WC = R (C + 4P + .5PT)$$

in which WC = working capital

R = 4 weeks' production rate

C = chemical cost per production unit

P = processing cost per production unit

T = production cycle, expressed as a fraction of 28 days

# MANUFACTURING COST

The total manufacturing cost is considered in this report to be the sum of the various processing costs plus general expenses. A detailed breakdown of the manufacturing costs is presented in Tables II and III.

Table II.--MANUFACTURING COST ESTIMATES--No Chemical Recovery

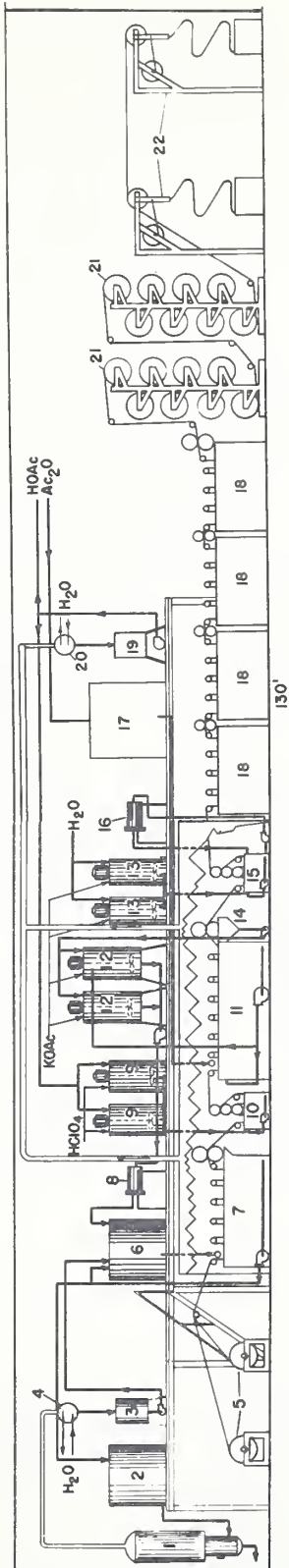
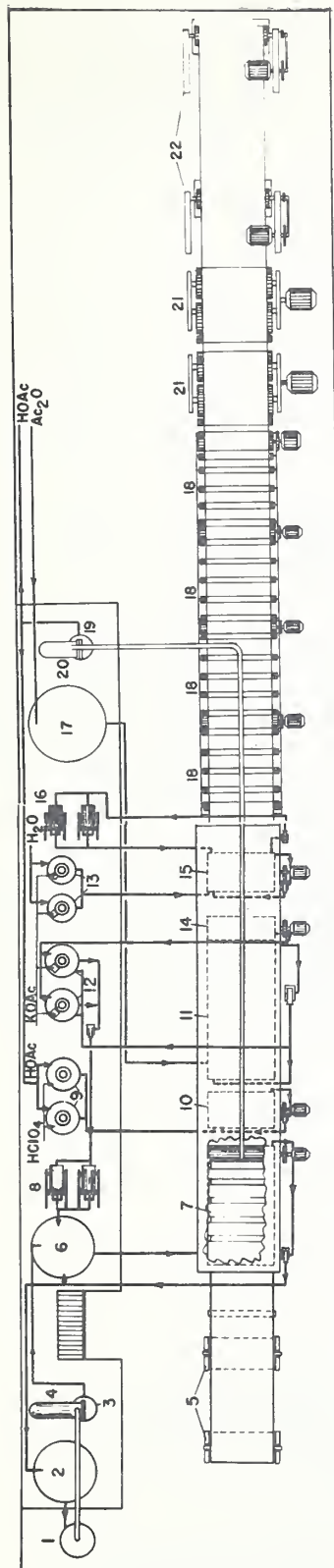
## YARN PROCESSING

| Item                                               | Large separate plant <sup>1</sup> | Plant as an addition to an existing textile mill <sup>2</sup> |           |           |
|----------------------------------------------------|-----------------------------------|---------------------------------------------------------------|-----------|-----------|
|                                                    |                                   |                                                               |           |           |
| Plant Capacity (M units).....pounds....            | 54,432                            | 3,780                                                         | 6,480     | 9,072     |
| Annual operation.....days.....                     | 350                               | 250                                                           | 250       | 350       |
| Daily operation.....hours.....                     | 24                                | 16 <sup>3</sup>                                               | 24        | 24        |
| <b>Processing Cost</b>                             |                                   |                                                               |           |           |
| Direct:                                            |                                   |                                                               |           |           |
| (a) Chemicals.....dollars....                      | 12,758,900                        | 886,000                                                       | 1,518,900 | 2,126,500 |
| (b) Labor.....do.....                              | 231,600                           | 32,600                                                        | 52,600    | 70,200    |
| (c) Supervision.....do.....                        | 23,200                            | 3,300                                                         | 5,300     | 7,000     |
| (d) Maintenance.....do.....                        | 120,820                           | 17,899                                                        | 21,845    | 25,866    |
| (e) Plant supplies.....do.....                     | 18,123                            | 2,685                                                         | 3,277     | 3,880     |
| (f) Utilities.....do.....                          | 195,718                           | 18,610                                                        | 29,060    | 41,440    |
| Subtotal.....do.....                               | 13,348,361                        | 961,094                                                       | 1,630,982 | 2,274,886 |
| Indirect:                                          |                                   |                                                               |           |           |
| (a) Payroll overhead.....do.....                   | 38,200                            | 5,400                                                         | 8,700     | 11,600    |
| (b) Gen'l plant overhead.....do.....               | 93,905                            | 13,450                                                        | 19,936    | 25,767    |
| (c) Control laboratory.....do.....                 | 26,000                            | 2,200                                                         | 3,700     | 5,200     |
| (d) Packaging.....do.....                          | 54,400                            | 3,800                                                         | 6,500     | 9,100     |
| Subtotal.....do.....                               | 212,505                           | 24,850                                                        | 38,836    | 51,667    |
| Fixed:                                             |                                   |                                                               |           |           |
| (a) Insurance.....do.....                          | 30,205                            | 5,966                                                         | 6,241     | 6,466     |
| (b) Property taxes.....do.....                     | 60,410                            | 11,932                                                        | 12,482    | 12,932    |
| (c) Depreciation.....do.....                       | 161,355                           | 33,999                                                        | 35,832    | 37,332    |
| Subtotal.....do.....                               | 251,970                           | 51,897                                                        | 54,555    | 56,730    |
| Contingencies.....do.....                          | 690,642                           | 51,892                                                        | 86,219    | 119,164   |
| Total processing cost.....do.....                  | 14,503,478                        | 1,089,733                                                     | 1,810,592 | 2,502,447 |
| Cost per unit.....cents per pound                  | 26.6                              | 28.8                                                          | 27.9      | 27.6      |
| <b>General Expenses</b>                            |                                   |                                                               |           |           |
| Gen'l admn. & office overhead.....dollars....      | 435,104                           | 32,692                                                        | 54,318    | 75,073    |
| Financing cost.....do.....                         | 446,410                           | 51,738                                                        | 67,781    | 83,079    |
| Sales cost.....do.....                             | 870,208                           | 65,384                                                        | 108,636   | 150,146   |
| Total gen'l expenses.....do.....                   | 1,751,722                         | 149,814                                                       | 230,735   | 308,298   |
| Cost per unit.....cents per pound                  | 3.2                               | 4.0                                                           | 3.6       | 3.4       |
| Total Manufacturing Cost.....dollars....           | 16,255,200                        | 1,239,547                                                     | 2,041,327 | 2,810,745 |
| Cost per unit untreated cotton.....cents per pound | 29.8                              | 32.8                                                          | 31.5      | 31.0      |
| Cost per unit of product.....do.....               | 26.4                              | 29.0                                                          | 27.9      | 27.4      |

<sup>1</sup> A self-sustaining plant equipped with 4 continuous partial acetylation ranges and other necessary equipment for processing in excess of 50 million pounds of yarn annually.

<sup>2</sup> Plant is addition to an existing textile finishing mill and includes 1 continuous partial acetylation range and other necessary equipment for processing between 3.8 and 9.1 million pounds of yarn and between 2.5 million and 12.1 million yards of 60-inch-wide, 2-yard sheeting or equivalent, annually.

<sup>3</sup> Net production time is 14 hours per day allowing 2 hours to start up and shut down.



1. CHEMICAL RECOVERY UNIT (EVAPORATOR)
2. EVAPORATOR FEEO TANK
3. CONDENSER SURGE TANK
4. CONDENSER
5. BEAMED FABRIC FEEO ASSEMBLY
6. ACTIVATION FEEO TANK
7. ACTIVATION RANGE TANK
8. FILTERS

9. CATALYST MAKE-UP & FEEO TANKS
10. CATALYST RANGE UNIT
11. REACTION RANGE UNIT
12. RECOVERED SOLUTION; CATALYST INACTIVATION TANKS
13. MAKE-UP & FEEO TANKS; CATALYST INACTIVATION RANGE UNIT
14. PADDER ASSEMBLY
15. CATALYST INACTIVATION RANGE UNIT
16. FILTERS

17. REACTION FEED TANK
18. WASH UNIT (4 SECTIONS)
19. CONDENSER SURGE TANK
20. CONDENSER
21. DRY-CAN ASSEMBLY
22. FOLDING UNITS

Figure 3.--Schematic plant layout.

Table III. MANUFACTURING COST ESTIMATES--No Chemical Recovery

## FABRIC PROCESSING

| Item                                              | Plant as an addition to an existing textile mill <sup>1</sup> |         |           |                    |                    |                     |
|---------------------------------------------------|---------------------------------------------------------------|---------|-----------|--------------------|--------------------|---------------------|
| Plant capacity (M units).....yards.....           | 2,520                                                         | 4,320   | 6,048     | 5,040 <sup>2</sup> | 8,640 <sup>2</sup> | 12,096 <sup>2</sup> |
| Annual operation.....days.....                    | 250                                                           | 250     | 350       | 250                | 250                | 350                 |
| Daily operation.....hours.....                    | 16 <sup>3</sup>                                               | 24      | 24        | 16 <sup>3</sup>    | 24                 | 24                  |
| <u>Processing cost</u>                            |                                                               |         |           |                    |                    |                     |
| Direct costs.....dollars...                       | 352,877                                                       | 589,048 | 817,471   | 657,309            | 1,107,834          | 1,543,330           |
| (a) Chemicals.....do.....                         | 295,300                                                       | 506,300 | 708,800   | 590,700            | 1,012,600          | 1,417,700           |
| (b) Labor.....do.....                             | 26,700                                                        | 42,800  | 57,400    | 26,700             | 42,800             | 57,400              |
| (c) Supervision.....do.....                       | 2,700                                                         | 4,300   | 5,700     | 2,700              | 4,300              | 5,700               |
| (d) Maintenance.....do.....                       | 17,954                                                        | 20,946  | 25,088    | 21,425             | 24,995             | 30,252              |
| (e) Plant supplies.....do.....                    | 2,693                                                         | 3,142   | 3,763     | 3,214              | 3,749              | 4,538               |
| (f) Utilities.....do.....                         | 7,530                                                         | 11,560  | 16,720    | 12,570             | 19,390             | 27,740              |
| Indirect Costs.....do.....                        | 28,539                                                        | 45,212  | 61,012    | 39,506             | 63,524             | 86,438              |
| (a) Payroll overhead.....do.....                  | 4,400                                                         | 7,100   | 9,465     | 4,400              | 7,100              | 9,500               |
| (b) Gen'l plant overhead.....do.....              | 11,839                                                        | 17,012  | 22,047    | 12,706             | 18,024             | 23,338              |
| (c) Control laboratory.....do.....                | 2,200                                                         | 3,800   | 5,300     | 2,200              | 3,800              | 5,200               |
| (d) Packaging.....do.....                         | 10,100                                                        | 17,300  | 24,200    | 20,200             | 34,600             | 48,400              |
| Fixed costs.....do.....                           | 51,965                                                        | 51,965  | 54,742    | 61,697             | 61,697             | 65,769              |
| (a) Insurance.....do.....                         | 5,985                                                         | 5,985   | 6,272     | 7,142              | 7,142              | 7,563               |
| (b) Property taxes.....do.....                    | 11,970                                                        | 11,970  | 12,544    | 14,284             | 14,284             | 15,126              |
| (c) Depreciation.....do.....                      | 34,010                                                        | 34,010  | 35,926    | 40,271             | 40,271             | 43,080              |
| Contingencies.....do.....                         | 21,669                                                        | 34,311  | 46,661    | 37,926             | 61,653             | 84,777              |
| Total processing cost.....do.....                 | 455,050                                                       | 720,536 | 979,886   | 796,438            | 1,294,708          | 1,780,314           |
| Cost per unit.....cents per yard                  | 18.1                                                          | 16.7    | 16.2      | 15.8               | 15.0               | 14.7                |
| <u>General Expenses</u>                           |                                                               |         |           |                    |                    |                     |
| Gen'l admn. & office overhead.....dollars...      | 13,652                                                        | 21,616  | 29,397    | 23,893             | 38,841             | 53,409              |
| Financing cost.....do.....                        | 38,793                                                        | 44,104  | 50,606    | 51,491             | 61,610             | 73,467              |
| Sales cost.....do.....                            | 27,304                                                        | 43,232  | 58,733    | 47,786             | 77,682             | 106,818             |
| Total general expenses.....do.....                | 79,749                                                        | 108,952 | 138,796   | 123,170            | 178,133            | 233,694             |
| Cost per unit.....cents per yard                  | 3.2                                                           | 2.5     | 2.3       | 2.4                | 2.1                | 1.9                 |
| Total Manufacturing cost.....dollars...           | 534,799                                                       | 829,488 | 1,118,682 | 919,608            | 1,472,841          | 2,014,008           |
| Cost per unit untreated cotton.....cents per yard | 21.3                                                          | 19.2    | 18.5      | 18.2               | 17.1               | 16.6                |
| Cost per unit of product.....do.....              | 21.3                                                          | 19.2    | 18.5      | 18.2               | 17.1               | 16.6                |

<sup>1</sup> Plant is addition to an existing textile finishing mill and includes 1 continuous partial acetylation range and other necessary equipment for processing between 3.8 and 9.1 million pounds of yarn and between 2.5 million and 12.1 million yards of 60-inch-wide, 2-yard sheeting or equivalent, annually.

<sup>2</sup> 2 thicknesses of material processed simultaneously.

<sup>3</sup> Net production time is 14 hours per day allowing 2 hours to start up and shut down.

## Processing Costs

Direct processing costs, which are found to represent a major portion of the total manufacturing costs, were obtained after the following considerations:

a. Chemical requirements shown on the Chemical Balance and Flow Diagram, Figure II, were determined from adjusted data obtained from laboratory, pilot-plant, and commercial scale operation and are considered realistic in view of the present stage of the process development. The unit costs of chemicals are as follows:

| <u>Chemical</u>       | <u>Weight ratio,<br/>chemical to cotton</u> | <u>Unit price, per pound</u> |
|-----------------------|---------------------------------------------|------------------------------|
| Acetic anhydride, 95% | 1.442/1.0                                   | 14                           |
| Perchloric acid, 70%  | 0.034/1.0                                   | 66                           |

| <u>Chemical</u>       | <u>Weight ratio,<br/>chemical to cotton</u> | <u>Unit price, per pound</u> |
|-----------------------|---------------------------------------------|------------------------------|
| Potassium acetate     | 0.036/1.0                                   | 28                           |
| Acetic acid, glacial  | 1.309/1.0                                   | 10                           |
| Potassium perchlorate | 0.022/1.0                                   | 17-1/2                       |

b. Direct labor costs were based on supporting warehouse labor at \$1.45 per hour plus the following process labor requirements per continuous partial acetylation range:

| <u>Plant size</u>  | <u>Labor</u>            | <u>Base wage rate per hour*</u> |
|--------------------|-------------------------|---------------------------------|
|                    |                         | <i>Dollars</i>                  |
| Large scale        | 1/2 skilled operator    | 2.15                            |
| (2 or more ranges) | 2 semiskilled operators | 1.45                            |
| Smaller scale      | 1 skilled operator      | 2.15                            |
| (1 range)          | 2 semiskilled operators | 1.45                            |

\*Labor cost includes night differential pay from 6:00 p.m. to 6:00 a.m. and was considered as the base wage plus 10 percent.

c. Supervisory costs were considered to be 10 percent of the direct labor (1, 8).

d. Plant maintenance costs were assumed to be 3, 3.5, and 4 percent of the total plant investment, increasing with an increase in hours per year of plant operation. Use of synthetic-resin-coated stainless steel equipment was of importance in considering maintenance costs (1, 8).

e. Plant operating supply costs were estimated at 15 percent of plant maintenance.

f. Utilities include steam, electrical power, and process water. Steam costs were computed for a requirement of 4 pounds of steam per pound of cotton, using unit steam costs of 50 cents and 70 cents per 1,000 pounds for the large and small plants, respectively. Electrical power costs were estimated using a unit cost of 1-1/2 cents per kilowatt-hour; requirements of about 280 kw. for the larger scale operation, and 55 kw. for the smaller scale operation. Process water costs were based on a requirement of 10 gallons of water per pound of cotton processed at a cost of 10 cents per 1,000 gallons.

Indirect processing costs are as follows:

a. Payroll overhead estimated at 15 percent of direct and supervisory labor cost and including social security, group life insurance, pensions, and vacation, holiday and absenteeism allowances (1, 8).

b. General plant overhead, for items not chargeable to any particular operation, such as engineering and medical services, general maintenance, fire protection facilities, receiving and salvage departments, and workmen's compensation insurance. This cost was estimated at 25 percent of direct and supervisory labor, plant maintenance, and plant operating supply costs.

c. Control laboratory costs including overhead were based on a control analysis time of 1/4 man-hour per 2 hours of production per range and a unit cost of \$5.00 per man-hour required for control analysis.

d. Unit packaging costs of 0.1 cent per pound of yarn processed and 0.4 cent per yard of fabric processed were used.

Fixed processing costs include insurance, property taxes, and depreciation. Insurance and property taxes were estimated to be 1 and 2 percent, respectively, of the plant investment. Depreciation costs were based on the estimated average life of 15 years for

process equipment (mostly acid handling) and electrical substation equipment (1, 8); 33 years for building and yard improvements (1); and 20 and 25 years, respectively, for steam generators and mechanical refrigeration (1).

A contingency cost of 5 percent of the direct, indirect, and fixed processing costs was added to compensate for estimating errors and unpredictable expenses which might occur, such as increases in chemical and labor costs, and losses which will result if material is rejected for not meeting product specifications (8).

### General Expenses

General expenses are those for general administrative overhead, sales and distribution, and financing. Administrative overhead, estimated at 3 percent of the total processing cost (1), includes management salaries, auditing charges, legal fees, communication expenses, and the like. Assuming bulk sales and distribution and limited advertising, sales costs were estimated to be 6 percent of total processing costs (1). Financing costs were calculated using an interest rate of 5 percent per annum on total capital (plant investment plus working capital) (1).

### CHEMICAL RECOVERY

As much as 47.5 percent of the total manufacturing cost represents chemicals lost in washing. Table IV shows manufacturing costs as they are, without chemical recovery, and as they appear with 90-percent recovery of acetic acid from the wash water.

Table IV. PA COTTON: YARN AND FABRIC MANUFACTURING COSTS

| Item                             | Cost with<br>reasonable chemical recovery |                        | Cost without<br>chemical recovery |                        |
|----------------------------------|-------------------------------------------|------------------------|-----------------------------------|------------------------|
|                                  | Untreated cotton                          | PA product             | Untreated cotton                  | PA product             |
| <u>Yarn</u><br>(Million pounds)  |                                           |                        |                                   |                        |
| Untreated:                       | <i>Cents per pound</i>                    | <i>Cents per pound</i> | <i>Cents per pound</i>            | <i>Cents per pound</i> |
| 54.432                           | 16.0                                      | 14.2                   | 29.8                              | 26.4                   |
| 3.780                            | 19.0                                      | 16.8                   | 32.8                              | 29.0                   |
| 6.480                            | 17.7                                      | 15.7                   | 31.5                              | 27.9                   |
| 9.072                            | 17.1                                      | 15.1                   | 31.0                              | 27.4                   |
| <u>Fabric</u><br>(Million yards) |                                           |                        |                                   |                        |
| Single thickness:                | <i>Cents per yard</i>                     |                        | <i>Cents per yard</i>             |                        |
| 2.520                            | 14.3                                      |                        | 21.3                              |                        |
| 4.320                            | 12.2                                      |                        | 19.2                              |                        |
| 6.048                            | 11.5                                      |                        | 18.5                              |                        |
| Double thickness:                |                                           |                        |                                   |                        |
| 5.040                            | 11.4                                      |                        | 18.2                              |                        |
| 8.640                            | 10.2                                      |                        | 17.1                              |                        |
| 12.096                           | 9.6                                       |                        | 16.6                              |                        |

Some of the recovery systems which might be used in the process are:

(1) Continuous countercurrent liquid-liquid extraction of acetic acid in the overflow from the first washer using an extraction media such as 70 percent of ethyl acetate and 30 percent of benzene, or 70 percent of tributyl phosphate and 30 percent of benzene, followed by fractionation. We have no information on the cost of this recovery, but estimates from industrial sources run as low as 1 cent per pound of acetic acid recovered. This recovery cost of 1 cent per pound of acetic acid was allowed in calculating the manufacturing costs based on 90-percent recovery of acetic acid in Table IV.

(2) Regeneration of acetic anhydride for reuse; by thermal decomposition (cracking) of acetic acid using phosphoric acid or a phosphate as catalyst. By this method acetic

anhydride would be obtained directly. Costs from industrial sources for this recovery run as low as 3 to 4 cents per pound of anhydride recovered.

(3) Recovery of 90 percent of the acetic acid remaining on the partially acetylated cotton after catalyst inactivation prior to washing. In laboratory tests conducted, this method had no apparent detrimental effect on the product, but since it has not been tried on a pilot plant scale it is only a possibility.

## ESTIMATED SERVICE CHARGE AND PAYOUT TIME

Calculated unit service charges and corresponding break-even points for partially acetylating cotton in each plant at profit levels representing payout times of 2 and 5 years and with reasonable chemical recovery are given in Tables V and VI. Payout time denotes the number of years in which the fixed capital investment is recovered from depreciation accruals and profits after taxes. Estimated gross income, from which each service charge was computed, was obtained by the summation of selected net profit, taxes, and manufacturing cost.

Table V. ESTIMATED SERVICE CHARGES AND BREAK-EVEN POINTS FOR 2 PROFIT LEVELS

### YARN PROCESSING

| Item                                                                                      | Large separate plant <sup>1</sup> | Plant as an addition to an existing textile mill <sup>2</sup> |           |           |
|-------------------------------------------------------------------------------------------|-----------------------------------|---------------------------------------------------------------|-----------|-----------|
| Plant capacity (M units).....pounds.....                                                  | 54,432                            | 3,780                                                         | 6,480     | 9,072     |
| Annual operation.....days.....                                                            | 350                               | 250                                                           | 250       | 350       |
| Daily operation.....hours.....                                                            | 24                                | 16 <sup>3</sup>                                               | 24        | 24        |
| <b>Estimated Service Charges</b>                                                          |                                   |                                                               |           |           |
| <b>1. Higher Profit:</b>                                                                  |                                   |                                                               |           |           |
| Profit after taxes (50% of fixed plant investment - depreciation).....annual dollars..... | 1,348,900                         | 264,324                                                       | 276,240   | 285,989   |
| Income tax <sup>4</sup> .....do.....                                                      | 1,392,733                         | 263,888                                                       | 276,291   | 286,438   |
| Gross profit.....do.....                                                                  | 2,741,633                         | 528,212                                                       | 552,531   | 572,427   |
| Manufacturing cost.....do.....                                                            | 8,720,706                         | 716,317                                                       | 1,144,363 | 1,554,849 |
| Gross income.....do.....                                                                  | 11,462,339                        | 1,244,529                                                     | 1,696,894 | 2,127,276 |
| Service charge per unit untreated cotton.....cents per pound.....                         | 21.1                              | 33.0                                                          | 26.3      | 23.4      |
| Service charge per unit product.....do.....                                               | 18.7                              | 29.2                                                          | 23.3      | 20.7      |
| <b>2. Lower Profit:</b>                                                                   |                                   |                                                               |           |           |
| Profit after taxes (20% of fixed plant investment - depreciation).....annual dollars..... | 442,747                           | 85,330                                                        | 88,997    | 91,996    |
| Income tax <sup>4</sup> .....do.....                                                      | 449,594                           | 77,588                                                        | 81,405    | 84,526    |
| Gross profit.....do.....                                                                  | 892,341                           | 162,918                                                       | 170,402   | 176,522   |
| Manufacturing cost.....do.....                                                            | 8,720,706                         | 716,317                                                       | 1,144,363 | 1,554,849 |
| Gross income.....do.....                                                                  | 9,613,047                         | 879,235                                                       | 1,314,765 | 1,731,371 |
| Service charge per unit untreated cotton.....cents per pound.....                         | 17.6                              | 23.3                                                          | 20.3      | 19.0      |
| Service charge per unit product.....do.....                                               | 15.6                              | 20.6                                                          | 18.0      | 16.8      |
| <b>Estimated break-even points<sup>5</sup></b>                                            |                                   |                                                               |           |           |
| 1. Higher Profit.....days operation.....                                                  | 81                                | 62                                                            | 73        | 82        |
| 2. Lower Profit.....do.....                                                               | 168                               | 144                                                           | 161       | 175       |

<sup>1</sup> A self-sustaining plant equipped with 4 continuous partial acetylation ranges and other necessary equipment for processing in excess of 50 million pounds of yarn annually.

<sup>2</sup> Plant is addition to an existing textile finishing mill and includes 1 continuous partial acetylation range and other necessary equipment for processing between about 3.8 and 9.1 million pounds of yarn and between 2.5 million and 12.1 million yards of 60-inch-wide, 2-yard sheeting or equivalent, annually.

<sup>3</sup> Net production time is 14 hours per day allowing 2 hours to start up and shut down.

<sup>4</sup> Taxes are sum of normal tax, surtax, and State taxes; normal tax = 25% gross profit; surtax = 22% (gross profit - \$25,000); State tax estimated at 4% gross profit.

<sup>5</sup> Break-even Point = 
$$\frac{(\text{Fixed cost plus } 0.3 \text{ (regulated cost)}) (\text{annual production})}{\text{Gross returns} - \text{variable cost} - 0.7 \text{ (regulated cost)}}$$

Table VI. ESTIMATED SERVICE CHARGES AND BREAK-EVEN POINTS FOR 2 PROFIT LEVELS

## FABRIC PROCESSING

| Item                                                                                    | Plant as an addition to an existing textile mill <sup>1</sup> |           |           |                    |                    |                     |
|-----------------------------------------------------------------------------------------|---------------------------------------------------------------|-----------|-----------|--------------------|--------------------|---------------------|
|                                                                                         |                                                               |           |           |                    |                    |                     |
| Plant capacity (M units).....yards.....                                                 | 2,520                                                         | 4,320     | 6,048     | 5,040 <sup>2</sup> | 8,640 <sup>2</sup> | 12,096 <sup>2</sup> |
| Annual operation.....days.....                                                          | 250                                                           | 250       | 350       | 250                | 250                | 350                 |
| Daily operation.....hours.....                                                          | 16 <sup>3</sup>                                               | 24        | 24        | 16 <sup>3</sup>    | 24                 | 24                  |
| 1. Higher Profit:                                                                       |                                                               |           |           |                    |                    |                     |
| Profit after taxes (50% of fixed plant investment - depreciation).....annual dollars... | 265,223                                                       | 265,223   | 269,324   | 316,806            | 316,806            | 335,064             |
| Income tax <sup>4</sup> .....do.....                                                    | 264,824                                                       | 264,824   | 269,092   | 318,512            | 318,512            | 337,516             |
| Gross profit.....do.....                                                                | 530,047                                                       | 530,047   | 538,416   | 635,318            | 635,318            | 672,580             |
| Manufacturing cost.....do.....                                                          | 360,337                                                       | 530,428   | 697,658   | 570,788            | 874,864            | 1,176,640           |
| Gross income.....do.....                                                                | 890,384                                                       | 1,060,475 | 1,236,074 | 1,206,106          | 1,510,182          | 1,849,220           |
| Service charge per unit untreated cotton.....cents per yard...                          | 35.3                                                          | 24.4      | 20.4      | 24.0               | 17.5               | 15.2                |
| Service charge per unit product.....do.....                                             | 35.3                                                          | 24.4      | 20.4      | 24.0               | 17.5               | 15.2                |
| 2. Lower Profit:                                                                        |                                                               |           |           |                    |                    |                     |
| Profit after taxes (20% of fixed plant investment - depreciation).....annual dollars... | 85,683                                                        | 85,683    | 86,174    | 102,560            | 102,560            | 108,178             |
| Income tax <sup>4</sup> .....do.....                                                    | 77,956                                                        | 77,956    | 78,467    | 95,522             | 95,522             | 101,369             |
| Gross profit.....do.....                                                                | 163,639                                                       | 163,639   | 164,641   | 198,082            | 198,082            | 209,547             |
| Manufacturing cost.....do.....                                                          | 360,337                                                       | 530,428   | 697,658   | 570,788            | 874,864            | 1,176,640           |
| Gross income.....do.....                                                                | 523,976                                                       | 694,067   | 862,299   | 768,870            | 1,072,946          | 1,386,187           |
| Service charge per unit untreated cotton.....cents per yard...                          | 20.8                                                          | 16.0      | 14.2      | 15.3               | 12.5               | 11.3                |
| Service charge per unit product.....do.....                                             | 20.8                                                          | 16.0      | 14.2      | 15.3               | 12.5               | 11.3                |
| Estimated Break-Even Points <sup>5</sup>                                                |                                                               |           |           |                    |                    |                     |
| 1. Higher Profit.....days operation....                                                 | 53                                                            | 61        | 68        | 54                 | 63                 | 69                  |
| 2. Lower Profit.....do.....                                                             | 129                                                           | 142       | 155       | 130                | 145                | 155                 |

<sup>1</sup> Plant is addition to an existing textile finishing mill and includes 1 continuous partial acetylation range and other necessary equipment for processing between about 3.8 and 9.1 million pounds of yarn and between 2.5 million and 12.1 million yards of 60-inch-wide, 2-yard sheeting or equivalent, annually.

<sup>2</sup> 2 thicknesses of material processed simultaneously.

<sup>3</sup> Net production time is 14 hours per day allowing 2 hours to start up and shut down.

<sup>4</sup> Taxes are sum of normal tax, surtax, and State taxes; normal tax=25% gross profit; surtax=22% (gross profit-\$25,000); State tax estimated at 4% gross profit.

<sup>5</sup> Break-even Point =  $\frac{(\text{Fixed cost plus } 0.3 \text{ (regulated cost)}) (\text{annual production})}{\text{Gross returns} - \text{variable cost} - 0.7 \text{ (regulated cost)}}$

## SUMMARY

## Manufacturing Costs

The estimated manufacturing cost for partially acetylating cotton yarn to 15-percent acetyl content in a continuous process, involving processing about 54 million pounds of scoured yarn annually with reasonable chemical recovery, is 14.2 cents per pound of product. A 15-percent acetyl content will increase the heat resistant characteristics of the cotton. For processing 3.8 and 9.1 million pounds of scoured yarn annually, the estimated manufacturing costs are 16.8 cents and 15.1 cents per pound of product, respectively.

The manufacturing costs for partially acetylating single-thickness, 60-inch-wide, 2-yard cotton fabric under similar conditions of processing are estimated to be 14.3 cents and 11.5 cents per linear yard for annual productions of about 2.5 and 6.0 million yards, respectively. Costs for processing two thicknesses of the above fabric simultaneously are 11.4 cents and 9.6 cents per linear yard, respectively, for annual productions of 5.0 and 12.1 million yards.

## Service Charges

The estimated unit service charges for the plant processing 54 million pounds annually are 18.7 cents per pound of product for amortizing the investment over 2 years,

and 15.6 cents per pound of product for amortizing the investment over 5 years. For the smaller plants, annually processing between 3.8 and 9.1 million pounds of yarn, calculated unit service charges for 2 years' amortization are 29.2 cents and 20.7 cents per pound of product; and for 5 years' amortization, 20.6 cents and 16.8 cents per pound of product.

For the plants processing between 2.5 and 6.0 million yards of single-thickness, 60-inch wide, 2-yard cotton fabric, the service charges range between 35.3 cents and 20.4 cents per linear yard and 20.8 cents and 14.2 cents per linear yard, respectively, for 2- and 5-year amortizations of the fixed investments. When simultaneously processing two thicknesses of fabric, the estimated unit service charges range between 24.0 cents and 15.2 cents per linear yard for 2 years' amortization and 15.3 cents and 11.3 cents per linear yard for 5 years' amortization.

It must be emphasized that the figures reported in these preliminary cost estimates are firm only to the extent of the validity of the many assumptions set forth and should not be compared with results of other estimates or processes without due consideration.

It should be further emphasized that the processing costs estimated in this report are predicated on specific continuous production rates; should these rates be reduced or should intermittent operations occur, the processing costs will increase accordingly.

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